USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Degradation of Groundwater Quality from Pumping-Induced Surface-Water Infiltration: Bacterial Contamination

Duration: 9/97- 8/99

Total Federal Funds: $43,954

Non-Federal Funds: $98,364

Principal investigators:

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Congressional district: Ohio 8th

Statement of critical regional water problem:

Drinking waters pumped from shallow glacial-fluvial aquifers are being contaminated with fecal coliform bacteria and it is likely that nearby polluted surface waters are the source of this contamination. Groundwater supplies drinking water for half of the US population [13] and pathogens in groundwater pose a major threat to human health. Between 1946 and 1977, 264 outbreaks and 62,273 cases of waterborne disease were attributed to contaminated groundwater [14]. Bacteria are the most common pathogenic contaminants. Many studies have observed bacterial transport through several hundred meters of a variety of aquifers ranging in grain size from pebbles to fine sand and have observed bacterial survival up to 1 month [7, 10]. Municipal wells located adjac ent to polluted streams and rivers are especially susceptible to contamination [4]. Due to downward hydraulic gradients induced by pumping, contaminated surface water may be drawn into the underlying aquifer and move towards drinking-water wells. Under US EPA guidelines, wells less than 50 ft from surface water **are** considered under the direct influence of surface water. From a regulatory standpoint, the Ohio EPA mandates that such groundwater be treated as if it were surface water and therefore req uires the water be treated with techniques for coagulation/flocculation, settling, filtration and disinfection. Upgrading typical groundwater treatment to include these techniques can be quite costly and in many circumstances prohibitive, resulting in wel l abandonment and the costly search for new water supplies. The studies cited above suggest that the 50-ft criterion will not be cautious enough in some settings. Adequate guidelines for appropriate separation distances need developing and should be based on our best ability to predict bacterial transport in a variety of hydrogeologic settings. Private wells are also susceptible to bacterial contamination. In a recent study of well-water quality in Iowa, 78% of wells tested in a volunteer sampling program were found to be positive for total coliform bacteria. The majority of these wells were shallow (67%) and were located > 100 ft from the closest active barnyard/feedlot and > 50 ft from a septic system (92%). Counterintuitively, there was an invers e relationship with distance from feedlots or septic systems and testing positive for total coliform bacteria. Clearly, both rural populations obtaining drinking water from private wells and municipal populations obtaining drinking water from aquifers adj acent to polluted surface waters are at risk of waterborne disease. Our objective in this study is to develop the ability to predict allochthonous (invasive, nonindigenous) bacterial transport through groundwater aquifers. Once allochthonous bacterial tra nsport through groundwater aquifers is better understood, greater protection of groundwater to be used as drinking-water sources will be possible. To meet our objective we will conduct laboratory experiments on the transport of allochthonous bacteria thro ugh groundwater sediments. Using these results, we will then construct a predictive model that balances utility with efficacy by including only necessary physical, chemical and biological parameters. Our goal is to produce a useful tool for researchers, r egulators and water system managers. The proposed research addresses the following NCRWI research priorities:

- Drinking water quality and availability and source protection
- Groundwater and surface water quality
- Conjunctive use - ground and surface water interface and connectivity

After thorough field testing (the initial test is included within this proposal) our results and model should provide a wide range of researchers, regulators and water system managers with a much needed tool for the protection of an important source of drinking water.

Statement of results and benefits:

This project will lead to a better understanding of those environmental factors that affect the transport and fate of allochthonous bacteria through groundwater systems. Of special importance is a better understanding of the importance of-the role that autochthonous (indigenous) bacteria play in this process. To accomplish our stated goals we will complete the following tasks: 1) determine breakthrough curves of a conservative tracer and coliform bacteria in groundwater sediments with a living autochth onous microbial community, a killed autochthonous microbial community and after removal of organic carbon; 2) quantitatively describe the autochthonous microbial community of groundwater sediments;

3) construct transport models that accurately simulate the breakthrough of bacteria observed in column experiments; 4) determine the physical, chemical and biological characteristics thought to have an impact on bacterial transport including grain-size , total organic carbon, sediment mineralogy, cation exchange capacity, solution pH and ionic strength; and 5) enumerate total coliform bacteria in creek water and groundwater. Upon fruition of the work we will produce one of the first (if not the first) q uantitative

descriptions of the shallow groundwater microbial community structure. This description will allow a quantification of the biological factors important in allochthonous bacterial transport through groundwater. We will use regression analysis t o couple calibrated bacterial-transport parameters with the physical, chemical and biological characteristics of groundwater sediments. The combination of a transport model with regression models relating transport model parameters to aquifer characterist ics constitutes a unique contribution to predicting bacterial fate in dynamic groundwater systems. Stochastic modeling techniques will provide a measure of the uncertainty associated with the resulting predictions.

Bacterial contamination of groundwater is a problem that directly affects drinking water quality in the US and worldwide. The developed combination of models will be specifically designed to assess the threat that surface-water sources have on nearby m unicipal wells, but should also have wide applicability to private, shallow-groundwater wells. The statistical component of the model provides wide applicability derived by taking into account many site-specific aquifer characteristics in estimating appro priate transport-model parameter values. In keeping with its utilitarian nature, the culmination of this study is a field test of the modeling approach. We have identified and acquired permission to use a site where bacterial contamination of a municipal well has already occurred. The field test will develop a permanent experiment site that we intend to use as the basis for future grant proposals as well as an outdoor teaching facility for geology and microbiology students. We believe this project could l ead to funding of other field sites with different hydrogeological characteristics for further development and refinement of the model. Future funding may also lead to packaging the model in a user-friendly format that automatically includes the regressio n analyses and written so that the model output includes a measure of the uncertainty of the predictions based on the variability of the aquifer characteristics included in the regression analyses.